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Computer Simulation Modeling: A Method for Predicting the Utilities of Alternative Computer-Aided Threat Evaluation Algorithms

James S. Ainsworth
Steven Kubala
U.S. Army Research Institute

September 1990

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This report describes the development of a computer model that simulates air defense engagements between a platoon of Air Defense Anti-Tank Systems (ADATS) and 20 aircraft. The model is programmed using SLAM II software and user-written FORTRAN inserts. Experimentation with the model yielded the necessary data for comparing the utilities of four computer-aided threat evaluation algorithms implemented in a target-rich environment. The model was run 100 times for each algorithm. The goal was to determine which of three experimental algorithms yielded results most similar to the results when using a more realistic but resource-intensive control algorithm. Experimental results provided support for using a target prioritization algorithm similar to the one formulated by the manufacturer of the ADATS, Martin Marietta.

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Computer Simulation Modeling: A Method for Predicting the Utilities of Alternative Computer-Aided Threat Evaluation Algorithms

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Human Factors in Training and Operational Effectiveness

FOREWORD

This technical report prepared by the Army Research Institute for the Behavioral and Social Sciences (ARI) describes the development of a computer mmodel that simulates air defense engagements between a platoon of Air Defense Anti-Tank Systems (ADATS) and 20 aircraft. It is part of a comprehensive effort to develop a general technology for evaluating the potential combat effectiveness of a variety of Army weapons systems being considered for acquisition. This particular effort was undertaken to determine the relative effectiveness of four alternative computer-aided threat evaluation algorithms projected for use with the ADATS.

The effort is included under the program task "Soldier-System Task Performance Modeling" of the ARI research project "Human Factors in Training and Operational Testing." The research was conducted in support of the Forward Area Air Defense (FAAD) Program of the U.S. Army Air Defense Artillery School (USAADASCH) in accordance with the Letter of Agreement "Manpower and Personnel Integration (MANPRINT) Support for the Forward Area Air Defense (FAAD) Program," dated 20 September 1986. The research program described in this report has been briefed to representatives of the USAADASCH Combat Development Directorate, and the TRADOC Analysis Command (TRAC).

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COMPUTER SIMULATION MODELING: A METHOD FOR PREDICTING THE UTILITIES OF ALTERNATIVE COMPUTER-AIDED THREAT EVALUATION ALGORITHMS

EXECUTIVE SUMMARY

Requirement:

The Army has a continuing requirement to evaluate the potential combat effectiveness of a variety of candidate weapon systems and associated software packages being considered for acquisition. Complete testing of the systems is both costly and time consuming. This is particularly true of operational testing where systems must be tested in realistic environments with units and soldiers that are typical of those that will be using the equipment if it is adopted. This research effort deals with the development of a computer model to evaluate the relative effectiveness of four computer-aided threat evaluation algorithms for the Air Defense Anti-Tank System (ADATS). The research is a component of a more comprehensive effort that has as its objective the development of a general technology for using computer simulation modeling as a substitute for selected portions of operational tests, thus saving both time and dollar resources. Of primary interest to this effort is the consideration of manpower, personnel, and training factors related to human performance on candidate weapon systems.

Procedure:

A computer model that simulates air defense engagements between a platoon of ADATS and numerous hostile aircraft was developed. The model is programmed via SLAM II software and user-written FORTRAN inserts. Experimentation with the model yielded the necessary data for comparing the utilities of four computer-aided threat evaluation algorithms implemented in a target-rich environment. The model was exercised 100 times for each algorithm and the dependent variables included "number of trigger pulls," "number of hostile targets killed," "number of hostile targets missed," and "average range at intercept for hostile targets killed." The goal was to determine which of three experimental algorithms yielded results most similar to the results yielded via a more realistic, but more resource-intensive control algorithm.

Findings:

Experimental results provided a modicum of support for using a target prioritization algorithm similar to the one formulated by the manufacturer of the ADATS, Martin Marietta.

Utilization of Findings:

This computer model is projected for use by tactics and doctrine developers at the U.S. Army Air Defense Artillery School, Fort Bliss, Texas, as a research tool for formulating target prioritization schemes, rules of engagement, reloading plans and procedures, and scenarios for tests, evaluations, and training exercises.

The experimental findings of the research will be useful as a source of information during the development of radar software for the ADATS.

COMPUTER SIMULATION MODELING: A METHOD FOR PREDICTING THE UTILITIES OF ALTERNATIVE COMPUTER-AIDED THREAT EVALUATION ALGORITHMS

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COMPUTER SIMULATION MODELING: A METHOD FOR PREDICTING THE UTILITIES OF COMPUTER-AIDED THREAT EVALUATION ALGORITHMS

Introduction

The U.S. Army is currently involved in a test and evaluation program associated with the acquisition of the Air Defense Anti-Tank System (ADATS). The system, manufactured by Martin Marietta (USA) and Oerlikon-Buehrle Ltd. (Switzerland), will fulfill frontline Line of Sight-Forward (Heavy) [LOS-F(H)] missions assigned to the Army's Forward Area Air Defense System (FAADS). In 1987, the U.S. Army chose ADATS as the winner of a Non-Developmental Item Candidate Evaluation (NDICE) held at White Sands Missile Range, New Mexico. Four candidate systems were evaluated in the following areas: (1) acquisition and tracking, (2) live fire, and (3) MANPRINT (Manpower and Personnel Integration). The latter area, MANPRINT, is an Army acquisition initiative that concerns the early identification and alleviation of weapon system problems in the domains of manpower, personnel, training, human factors engineering, system safety, and health hazards. One MANPRINT problem noted for the ADATS during the NDICE was the excessive amount of time required for radar operators to prioritize targets in multiple-target environments. Evaluators described the problem as follows: "Target prioritization is solely an operator function. This delays FAADS reaction time and raises significant tactical doctrine issues concerning target criticality and who makes the prioritization decision." Martin Marietta's response to this criticism was that a planned product improvement would alleviate the problem on future versions of ADATS, i.e., future versions would use onboard computers to implement a target prioritization algorithm as part of an automatic, second-by-second, computer-aided threat evaluation (CATE). According to Martin Marietta, the use of this computer-generated information would expedite a critical decision-making task performed by the radar operator--i.e., determining which target to handoff to the gunner (Moulton, 1988).

Current versions of the ADATS have CATE systems installed, but the software is still under development by the radar manufacturer, Contraves Italiana, a subcontractor to Martin Marietta (USA). Contraves Italiana will deliver the final version of the software to Martin Marietta in 1991. Until then, the subcontractor will be concerned with the research question addressed by this report: What target prioritization algorithm would optimize the performance of the ADATS on future battlefields?

Researchers with the U.S. Army Research Institute have developed a method for evaluating MANPRINT issues that are related to the deployment of selected weapon systems. The method includes the development of a time-based, sequentially-processed, computer simulation model programmed via SLAM II software (Pritsker, 1986) and user-written FORTRAN inserts. The initial model developed via the method simulates air defense engagements and is limited in scope, covering only the interactions among a platoon of four fire units and numerous aerial targets. No attempt was made to simulate the movement of ground forces and the effects that these movements would have on air defense engagements. However, the model can be used to provide insights into narrowly-focused research questions such as the one stated above.

Problem

An ADATS crew consists of a radar operator, a gunner, and a driver. One of the duties of the radar operator is to evaluate the aerial threat posed to the ADATS fire unit and to the critical asset protected by the fire unit. Threat evaluation is an ongoing concern for the radar operator, but it is particularly important when the gunner is idle, i.e., when the gunner is not engaging a target. At this time, the radar operator must prioritize the targets displayed on his radar scope, select the highest priority target, and handoff this target to the gunner. Handoff deals primarily with the transfer of position and velocity data relevant to the target handed off. This information is transferred to the turret system which automatically slews the turret to the azimuth of the selected target. The gunner then searches for the target by moving his electro-optic or forward looking infrared (FLIR) equipment in the vertical direction, i.e., he searches for the target at different elevations for a given azimuth.

Algorithms for evaluating the threat posed by multiple-target environments are typically complex and difficult to implement in stressful situations. Therefore, computerized decision-making aids are being developed to ensure that selected factors are considered in a specified order. Examples of factors considered in most target prioritization algorithms are: 1) type of aircraft (fixed wing or rotary wing), 2) speed of aircraft, 3) distance of aircraft from fire unit, 4) distance of aircraft from critical asset, 5) flight profile of aircraft (attacking, transiting, or retreating), and 6) distance of aircraft from Primary Target Line (PTL) assigned to the fire unit. Martin Marietta's Computer-Aided Threat Evaluation (CATE) algorithm considers information about target type, distance to defended asset, time to reach defended asset, and Identification--Friend or Foe (IFF) data. The CATE routine computes target priorities once every second for those targets identified as "hostile" and those targets not yet identified. A detailed description of the CATE algorithm follows:

> The CATE algorithm partitions the search area into two sets of concentric zones. The zones for fixed-wing aircraft are shown in Figure 1(A). The inner circle defining Zone 1 has radius R_{FW} equal to the effective range of the armament carried by the fixed-wing threat. The outer circle has a radius R_{LOS} equal to the effective range of the LOS-F(H) missile. The fire unit or the relatively close, defended asset may be at the center of the concentric zones; the radar operator selects which one is at the center. The region between the inner and outer circles is defined as Zone 2. The region outside the R_{LOS} circle is Zone 3. The zones for hovering helicopters are shown in Figure 1(B). The outer circle, representing the LOS-F(H) missile intercept capability, is unchanged. The inner circle has a radius R_{HH} which defines the effective range of the missiles carried by helicopters. Helicopters are assumed to carry longer-range missiles than fixed-wing aircraft; therefore, R_{HH} is greater than R_{FW}.

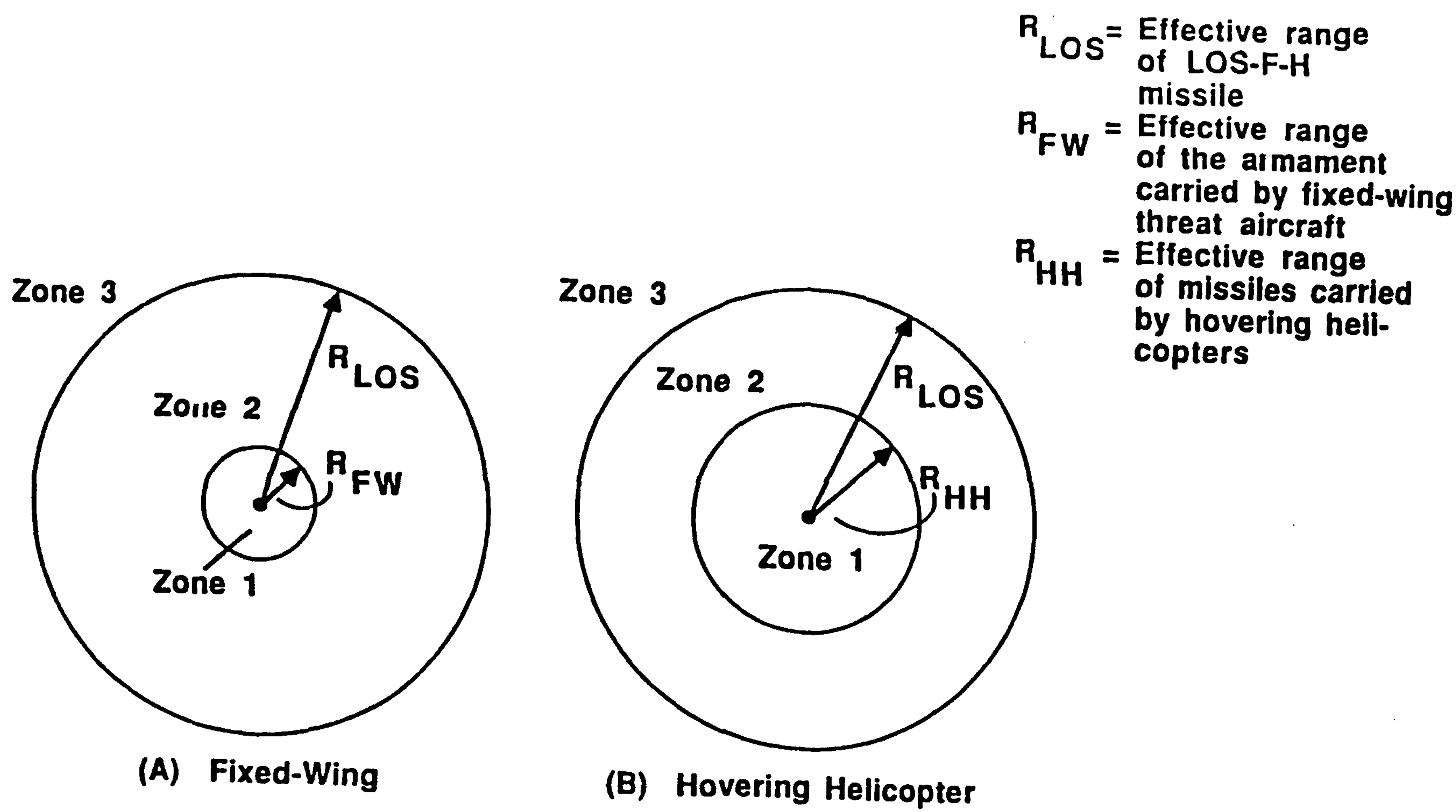


Figure 1. Target Prioritization Zones (from Moulton, 1988)

The CATE algorithm assumes that the LOS-F(H) has a fixed target engagement time (T_E) -- the time from "handoff of target to gunner" to "missile intercept". The constant T_E includes reaction time and flyout time, so T_E is independent of the positions of the fire unit, the defended asset, and the threat aircraft. Target positions are projected T_E seconds into the future, based upon their present positions and velocity vectors. Targets with projected positions within Zone 1 are designated as high priority (Class 1), since these targets can destroy the fire unit or the defended asset. Targets with projected positions within Zone 2 are designated as medium priority (Class 2), since these targets cannot destroy the fire unit or defended asset but can be intercepted by a LOS-F(H) missile. Targets with projected positions within Zone 3 are designated as low priority (Class 3), since these targets cannot destroy the fire unit or defended asset, and cannot be intercepted by a LOS-F(H) missile.

Martin Marietta is currently discussing what numerical values to use for the constants R_{FW}, R_{HH}, R_{LOS}, and T_E. These values will greatly influence the class membership assigned to each target. Once each target is assigned to a class, further prioritization is based on aircraft type, aircraft speed, detection time, and time-to-intercept. The CATE algorithm prioritizes aerial targets in the following manner:

Priority	Target Type
1 (highest)	Hovering helicopters and helicopters moving less than 50 meters/second, Class 1
2	Fixed-wing and helicopters moving greater than or equal to 50 meters/second, Class 1
3	Hovering helicopters and slow-moving helicopters, Class 2
4	Fixed-wing and fast-moving helicopters, Class 2
5	Receding targets with outward radial velocity less than 50 meters/second, Class 1 or 2
6	Hovering helicopters and slow-moving helicopters, Class 3
7	Fixed-wing and fast-moving helicopters, inbound, Class 3
8	Receding targets with outward radial velocity less than 50 meters/second, Class 3
9 (lowest)	Receding targets with outward radial velocity greater than 50 meters/second, Class 1, 2, or 3

Within a specific priority group, hovering and slow-moving helicopters are prioritized in the order in which they are detected (i.e., first detected is highest priority); fixed-wing aircraft and fast-moving helicopters are prioritized according to the theoretical, extrapolated time-to-last-useful-intercept (i.e., shortest time is highest priority).

The ADATS' Track-While-Scan (TWS) radar can track up to 10 locally detected targets at once. When the fire unit is netted to other radar systems, TWS can also track up to 10 remotely detected targets. CATE examines the priority of all the targets currently being tracked. The 10 highest priority targets are assigned a target number from 1 to 10. Each of these targets is displayed on the radar scope with the target number, velocity, direction, and the IFF identification symbol. If netting exists, the additional 10 targets within the TWS file are displayed on the radar scope, but with only their IFF identification symbols presented. [Excerpts from Martin Marietta's response to ARI's CET MANPRINT debriefing held on 8 January 1988. See Moulton (1988) for the complete response.]

The problem addressed in this research concerns the selection of the value for T_E in the CATE algorithm. Should T_E be a constant or a variable? If it is a constant, which constant would yield the best, or at least an acceptable, evaluation of the aerial threat?

Method

Computer Simulation Modeling

Computer simulation modeling is a technology which can be used to determine the relationship between MANPRINT-related aptitudes of crewmembers and combat effectiveness of military systems. If design engineers were informed about how their weapon systems and equipment would likely perform if operated by personnel of varying aptitudes, abilities, and training, they could take appropriate corrective action (if necessary). This could be done by making hardware or software changes, reallocating functions between man and machine, recommending personnel selection strategies, and recommending appropriate training strategies. Tactics and doctrine developers could use the results of computer models to formulate target prioritization schemes, rules of engagement, reloading plans and procedures, and scenarios for tests, evaluations, and training exercises. This latter use had the greatest influence on the development of the current model.

a. Model Conceptualization. In order to obtain as much realism as possible in a computer simulation model of a LOS-F(H) engagement sequence, ARI researchers relied heavily on subject-matter experts in the Tactics and Doctrine Department of the U.S. Army Air Defense Artillery School (USAADASCH), Fort Bliss, Texas. These experts provided information about how a LOS-F(H) weapon system would be deployed on a battlefield, flight profiles of enemy and friendly aircraft, task sequences that would likely be followed by crewmembers, and dynamic battlefield conditions that should halt an engagement sequence, e.g., the masking of a target by terrain features; a "foe" to "friend" ID change for a target; and the destruction of a target by another fire unit.

Consultation with subject-matter experts at USAADASCH led to the formulation of eight sequential task periods for an ADATS engagement sequence. The task periods were labeled as follows: 1) Surveillance, 2) Detection, 3) Threat Analysis, 4) Handoff, 5) Selection of Tracking Mode, Sensor Type, and Field of View Type; Visual Identification, 6) Tracking, Ranging, Fire Decision, Trigger Pull, 7) Tracking To Intercept or Miss, and 8) Termination. Since the task periods are sequential in nature, a time-based, sequentially-processed computer simulation model was appropriate. [See Figure 2 for the events that start and end each task period and the data sources for these events.]

ARI researchers then decided what model outputs were needed to answer the research question of interest and what model inputs were needed to yield these outputs. Outputs from the model include the following:

- number of hostile targets killed
- number of hostile targets missed
- number of friendly targets killed
- number of friendly targets missed
- average range at intercept for hostile targets killed
- time-averaged number of aerial targets waiting for gunner's attention
- number of ordnance releases made by hostile targets.

Inputs to the model include the following:

- digitized terrain for Fort Hunter Liggett, California, where a Force Development Test and Evaluation took place for the ADATS
- flight profiles of aircraft over the terrain
- location of four ADATS fire units on the terrain
- dimensions of sector of fire for each fire unit
- direction of Primary Target Line (PTL) for each fire unit
- dimensions of fire zone envelope for each fire unit
- task time distributions for ADATS crewmembers
- rules of engagement
- threat evaluation algorithm for prioritizing aerial targets
- missile flyout equation for the ADATS missile
- probability of single shot kill (Pssk).

The inputs and outputs were affected by numerous assumptions made during the conceptualization phase of model development. A few of the assumptions are listed below:

- The 100-meter resolution of the digitized terrain was sufficiently fine to permit the collection of valid data during simulation.
- The threat posed by the simulated air-land battle allowed the four fire units to remain stationary in a two up-two back configuration.
- The radar coverage area (RCA) for a fire unit is hemisphere-shaped and is centered on the fire unit.
- The sector of fire or zone of interest (ZI) for a fire unit is an assigned portion of the hemisphere-shaped RCA.
- A target within a RCA for a fire unit is detected by the fire unit's radar system if the target is not masked by terrain.
- All radar, electro-optical, and FLIR systems perform reliably, i.e., no hardware malfunctions occur during the simulation.

Figure 2. Sequential Task Periods for ADATS and Sources of Time Data

TASK PERIOD	NAME	START EVENT / DATA SOURCE	END EVENT / DATA SOURCE
*1	Surveillance	Creation Time for Aircraft / ARI Modeler	Blip Appears on Radar Scope / Video Tape
2	Detection	Blip Appears On Radar Scope / Video Tape	Commander Depresses Deadman Switch / Pulse Code Modulator
*3	Threat Analysis	Commander Depresses Deadman Switch / Pulse Code Modulator	Commander Depresses TRK ASGN and RDY/ENG Buttons / Pulse Code Modulator
4	Handoff	Commander Depresses TRK ASGN and RDY/ENG Buttons / Pulse Code Modulator	Gunner Hits Deadman Switch / Pulse Code Modulator
5	Selection of Tracking Mode, Sensor Type, & Field of View Type; Visual ID	Gunner Hits Deadman Switch / Pulse Code Modulator	Gunner Visually Identifies Target / Audio Tape
*6	Tracking, Ranging, Fire Decision, Trigger Pull	Gunner Visually Identifies Target / Audio Tape	Gunner Pulls Trigger / Pulse Code Modulator
*7	Tracking to Intercept or Miss	Gunner Pulls Trigger / Pulse Code Modulator	Missile Intercept Or Miss / Video Tape
8	Termination	Missile Intercept Or Miss / Video Tape	Gunner Depresses "Mission Reset" and "Mission Prep" Buttons / Pulse Code Modulator

* Time Interval for this task period will not be randomly drawn from NDICE-established distributions, because end of task period is too scenario-dependent. Special rules for ending this period will be encoded for computer simulation, so that total elapsed time from the beginning of Period 1 to the end of Period 8 will be more realistic for each aircraft.

- The flight paths of aircraft, simulated via pre-planned waypoint-to-waypoint inputs to the model, represent the dynamic real-time movements of aerial targets.
- Tactical doctrine allows more than one fire unit to fire at the same target if the target is in two or more zones of interest simultaneously.

b. Model Translation. The first step in translating a conceptualized model of an air defense engagement sequence into a computer model was the selection of a computer simulation language that can easily handle the dynamics involved in a simulated air-land battle. SLAM II (Simulation language for alternative modeling), a FORTRAN-based computer simulation language developed by Pritsker and Associates, was chosen because it is based on a universal scientific language (FORTRAN), it is a simulation language commonly used by the industrial engineering community for determining optimal solutions to complex problems, it offers a high degree of flexibility to the modeler, and the private industry developers of SLAM II have a reputation for continuously improving their software.

The second step in translating a conceptualized model into a computer model was the choice of an object of analysis, or type of entity that would "flow" through a SLAM II network. In order to model scenario factors related to enemy and friendly aircraft (e.g., type of aircraft, speed of aircraft, and ordnance carried by aircraft) and to model the effects of human traits and abilities on the performance of ADATS crewmembers (e.g., the effects of visual scanning ability, visual acuity, field independence and dependence, tracking ability, experience in Military Occupational Specialty (MOS), and relevant aptitudes measured via the Armed Services Vocational Aptitude Battery (ASVAB)), ARI modelers selected a compound entity (i.e., a target-crew entity) as the type of entity to flow through a SLAM II network. Attributes of targets, as well as attributes of crewmembers, were assigned to each target-crew entity processed during the simulated air-land battle. These attributes were used in the simulation for two purposes: 1) to effect a degree of realism by influencing the dynamics of the simulated air-land battle and 2) to insure that task performance times for specific crewmembers were drawn from research-based time distributions that are dependent upon the human traits and abilities relevant to the tasks being performed.

The third step in translating a conceptualized model into a computer model was the development of a flowchart, using SLAM II nodes and branches to show 1) how entities would be sequentially processed in a time-based network, and 2) how user-written FORTRAN inserts would interplay with the network to customize a complex, dynamic model that simulates a complex, dynamic war. [See Appendix A for an example of the flowchart for this model.] The influence of human performance factors was modeled in several ways, such as: 1) a look-up table for selecting the probability that a gunner makes a correct visual identification of an aircraft. [The table is encoded as a FORTRAN insert and is indexed by type of aircraft and slant range of aircraft from the fire unit in question.], 2) rules for determining task performance times that are modified or influenced by crewmember traits and abilities relevant to the tasks performed. [The rules are encoded as FORTRAN inserts.], 3) rules for determining the proper course of action following a trigger pull, i.e., surveillance for a new target, another trigger pull at the same target, a mandatory reload, or an optional reload. [The rules are encoded as conditional branches of the network.], and 4) rules for determining whether manual tracking or automated tracking is performed. [The rules are encoded as probabilistic branches in the network.]

The fourth step was the conversion of the flowchart nodes and branches into SLAM code. [A copy of the SLAM code can be obtained from the senior author.]

The fifth step was the development of a method for inputting scenario data, such as waypoint-to-waypoint flight profiles of aerial targets. [See Appendix B for an example and a description of the YTRACK DATA file which is used to input scenario information for the model.]

The sixth step was the writing of the FORTRAN subroutines necessary for calculating the second-by-second values associated with three status arrays and subroutines for using these values in the simulation. The TNOW and TNOW-1 information, i.e., current-second and previous-second information, entered into these arrays was used to trigger dynamic changes within the model and to determine how entities traversed through conditional branches of the SLAM II network. [A copy of the FORTRAN code can be obtained from the senior author. See Appendix C for descriptions of the three status arrays.]

c. Model Validation. Prior to the development of a computer simulation model for a platoon of ADATS (i.e., four fire units), a one fire unit model was developed. The model simulated air defense engagements between one fire unit and many aerial targets. Sensitivity analyses for a one-on-many LOS-F(H) model were conducted. The general approach was to vary one input variable at a time to see if the variation had a significant effect on model output. All other variables, including the flight profiles of six hostile aircraft and six friendly aircraft, were held constant. Three input variables were varied separately. They were: 1) a time distribution representing a radar operator's task performance times for detecting a blip on his radar scope, 2) a time distribution representing a gunner's task performance times for tracking, selecting an appropriate optical sensor, selecting an appropriate field of view, and then visually identifying a target, and 3) a probability look-up table that controls whether a gunner visually identifies a target as a friend or a hostile. Each input variable, either a time distribution or a probability look-up table, was varied in three ways (representing low, medium, and high abilities to perform the relevant tasks) and 40 iterations of the model were run for each way an input variable was altered. This resulted in the model being run 360 times for a particular set of random number seeds. A second set of random number seeds was used and the model was run another 360 times. A third set of random number seeds was used and the model was run another 360 times.

The output variables analyzed were those directly or indirectly related to the battlefield effectiveness of the weapon system. Thirty-eight of the output variables (or dependent variables) were derived from SLAM II software. Among the 38 were: % of Time Crew Was In Surveillance and Target Selection Mode; % of Time Crew Was In Engagement Mode; % of Time Crew Perceived A Particular Threat Condition (1, 2, 3, or 4); and Time-Averaged Number of Targets On The Radar Scope. Thirteen of the output variables (or dependent variables) were derived from user-written FORTRAN subroutines. Among the thirteen were: Number of Trigger Pulls, Number of Targets Killed, Number of Targets Missed, Average Range At Impact For Targets Killed, Number of Hostile Targets Killed, Number of Friendly Targets Killed, and Loss Exchange Ratio. One-way Analyses of Variance (ANOVAs) were completed and several statistically significant results were obtained. The results indicate that output from the one-on-many LOS-F(H) model is sensitive to variations in input. ARI researchers concluded the following:

1) the one-on-many LOS-F(H) computer model is internally valid, 2) future experimentation with the one-on-many LOS-F(H) model should use a trial size of at least 40--so that average values derived from multiple runs of the model stabilize regardless of the random number seeds used, and 3) future experimentation with the one-on-many LOS-F(H) model should follow the model-test-model paradigm for establishing the external validity of the model.

d. Broadening the Scope of the Model. Recently completed work has broadened the scope of ARI's LOS-F(H) computer simulation model. It has been altered from a one-on-many model to a four-on-many model. This change makes the simulation more realistic, since ADATS fire units are likely to fight as a platoon of four--using Command, Control, and Intelligence (C2I) information and other communication links among themselves and among other friendly components on the battlefield. The upgraded, more realistic model has greater utility to its primary users, civilian and military analysts in the Tactics and Doctrine Division of the Directorate of Concepts, Studies, and Doctrine, USAADASCH, Fort Bliss, Texas. These personnel have a short-term need to use a platoon model for scenario development for field exercises and operational tests. They have a long-term need to use a platoon model to provide insights into tactical and doctrinal questions related to such things as target prioritization schemes, pass-off rules among fire units, and reloading rules.

The threat scenario used for the platoon model was patterned after a defensive scenario planned for the ADATS FDTE II at Fort Hunter Liggett, California. The flight profiles for 20 aircraft were input to the model by specifying 1) waypoints along the flight path for each sortie, 2) the constant or varying velocities flown between waypoints, and 3) the simulation time that each sortie commenced flying its pre-planned route. The 20 aircraft included the following:

2 slow-moving, rotary wing hostiles flying as a pair
2 fast-moving, rotary wing hostiles flying as a pair
4 pop-up, rotary wing hostiles, two pairs popping up at different locations
4 attacking, fixed wing hostiles, two pairs striking from different locations
2 transiting, fixed wing hostiles flying as a pair
2 slow-moving, rotary wing friends flying alone along different routes around the perimeter of battlefield
1 pop-up, rotary wing friend
1 transiting, fixed wing friend
2 attacking, fixed wing friends.

ARI researchers have concluded that the four-on-many model is internally valid, i.e., that the SLAM II and FORTRAN codes do what they are supposed to do and logically represent the subject matter experts' descriptions of the battlefield activities of an ADATS platoon. Sensitivity analyses and external validity studies should be performed on the four-on-many model to improve its utility as a research tool.

Experimental Design

A completely randomized design (i.e., a one treatment variable, independent-groups design) was used for experimentation with the SLAM II,

four-on-many computer simulation model. The design was used to compare the battlefield effectiveness associated with four threat evaluation algorithms. Each algorithm was encoded as a FORTRAN subroutine in the model. One algorithm is similar to the one developed by Martin Marietta; it determines the priorities of aerial targets after predicting their positions following 10 seconds of flight. These positions are determined by making straight-line projections for predicted flight paths (using "current second" and "previous second" position data) and calculating how far each target would fly in 10 seconds along the straight-line flight path at its current velocity. The algorithm assumes that all intercepts occur 10 seconds following handoff, i.e., that the target engagement time (T_E) is a constant 10 seconds. This assumption ignores known information concerning flyout times and travel distances for the ADATS missile. For instance, if the projected position of a target after 10 seconds of flight is 6 km away from a fire unit, the algorithm assumes an ADATS missile would intercept the target in 10 seconds; if the projected position of a target after 10 seconds of flight is 3 km away from the fire unit, the algorithm assumes an ADATS missile would intercept this target in 10 seconds also. Thus, the algorithm ignores information that is known when the projections are made, such as 1) the relative positions of the fire unit, the defended asset, and the aerial target and 2) the flyout equation for the ADATS missile. The experimental condition associated with this algorithm is labeled "Experimental Condition B" in the Results section below.

Two of the other algorithms are slightly modified versions of the algorithm described above. One assumes $T_E = 6$ seconds; the experimental condition associated with this algorithm is labeled "Experimental Condition A" in the Results section. The other assumes $T_E = 14$ *seconds*; the experimental condition associated with this algorithm is labeled "Experimental Condition C" in the Results section. The T_E values chosen for the experimental groups (6, 10, 14) were evenly-spaced in order to detect the presence of linear trends in the output data, if any existed. The fourth algorithm was developed by ARI researchers; it determines the priorities of aerial targets after predicting intercept positions following varying amounts of flight time. The algorithm assumes that the target engagement time (T_E) varies with each engagement, depending upon the relative positions of the fire unit and the aerial target, the velocity vector of the target, and the flyout equation for the ADATS missile. The control or baseline condition associated with this algorithm is labeled "Control Condition D" in the Results section.

The basic difference among the four algorithms is the method for projecting a target's position at intercept if handoff occurs at the current time. When determining the projected position of the target at intercept, the algorithms for Experimental Conditions A, B, and C ignore the flyout equation for the ADATS missile. Each algorithm assumes that target engagement times are constant, regardless of the location of the target when handoff occurs. The algorithm for Control Condition D assumes that target engagement times are variable; it does not ignore the missile flyout equation. Thus, the algorithm associated with Control Condition D is the one that makes the best use of all known information and the one that makes the most realistic predictions about where and when intercepts would occur. It is also the one that would be the most difficult to implement on a small computer. The goal for the experiment was to determine if Experimental Condition A, B, or C produced experimental results that are similar to the baseline results produced by Control Condition D. If so, the algorithm associated with the best alternative condition (A, B, or C) would be recommended for use with the CATE system.

Procedure

The four-on-many model was exercised 100 times for each of the four types of algorithms. All inputs to the model were held constant across the four conditions, except the FORTRAN subroutine depicting a particular threat evaluation algorithm for prioritizing aerial targets.

Data Analysis

One-way analyses of variance were used to determine if the four algorithms produced outputs that were significantly different. The researchers separately analyzed 150 dependent variables, such as number of trigger pulls by platoon, number of targets killed by platoon, average range at intercept for targets killed by platoon, number of trigger pulls by each fire unit, number of targets killed by each fire unit, average range at intercept for targets killed by each fire unit (see Appendix D for a list of the dependent variables analyzed). Since so many dependent variables were analyzed separately, one would expect some of the ANOVAs to yield statistically significant differences due to chance factors alone. Such a large number of dependent variables was analyzed because the research was exploratory in nature, with no formally stated hypotheses. [The researchers did have an underlying notion that if a constant T_E is used in the CATE algorithm, the constant should at least be dependent upon the type of terrain fought on (flat, hilly, or mountainous) and the type of aerial assault being experienced (helicopter, fixed-wing, or mixed). The answers to complex questions related to different terrain types and assault types must come from further research.]

Due to the voluminous amount of data produced by this exploratory research, the procedures used for follow-on analyses related to platoon performance were different from the procedures used for follow-on analyses related to individual fire unit performance. For example,

a) If a one-way ANOVA with platoon data yielded an F-ratio with a p-value of .10 or less, further analyses were conducted to determine whether each experimental condition (A, B, and C) yielded results that were significantly different from the results yielded by the control condition (D). Dunnett's t tests were used for these follow-on analyses because such tests allow researchers to evaluate the differential effects of two or more experimental conditions in comparison with a control or baseline condition. [For a detailed explanation of the statistical technique, see Dayton, 1970, p. 49.]

b) If a one-way ANOVA with fire unit data yielded an F-ratio with a p-value of .10 or less, the three means for the experimental conditions were rank ordered according to their closeness to the mean for Control Condition D--with a ranking of "1" representing the experimental mean closest to the control mean and a ranking of "3" representing the experimental mean farthest from the control mean. The ranked data for all dependent variables whose ANOVAs yielded p-values of .10 or less were then subjected to an ANOVA for ranked data. Rather than an F statistic, the chi-square statistic was used to test the hypothesis of no difference in mean rank for the three experimental conditions. [For a detailed explanation of the statistical technique, see Winer, 1971, pp. 301-302.]

Results

Twenty-eight (28) of the 150 one-way ANOVAs yielded results significant at the $p \leq .10$ level. Three (3) of these were associated with the platoon; the dependent variables were V62, V143, and V94. (See a, b, and c below.) Twenty-five (25) were associated with individual fire units; the dependent variables were V2, V4, V6, V8, V10, V12, V24, V39, V52, V54, V55, V56, V60, V66, V67, V69, V75, V90, V104, V106, V114, V116, V118, V119 and V124. (See d below.)

a. Dependent Variable V62 - Number of Targets Killed by Platoon

ANOVA Results:

Experimental Condition	Mean	Std.Dev	F	p	Order of Closeness to D
A	11.330	1.965	2.47	.0615	BCA
B	11.870	1.813			
C	11.340	1.929			
Control Condition					
D	11.820	1.800			

Dunnett's t Results:

(1) Condition A vs. Condition D

$t = -1.8449712$

This t statistic is less than the critical value (i.e., $t = 2.37$) found in Dunnett's table ($\alpha = .05$, two-tailed test). Therefore, the mean number of targets killed by the platoon in Condition A is not significantly different from the mean number in Condition D.

(2) Condition B vs. Condition D

$t = .1882624$

This t statistic is less than the critical value (i.e., $t = 2.37$) found in Dunnett's table ($\alpha = .05$, two-tailed test). Therefore, the mean number of targets killed by the platoon in Condition B is not significantly different from the mean number in Condition D.

(3) Condition C vs. Condition D

$t = -1.8073187$

This t statistic is less than the critical value (i.e., $t = 2.37$) found in Dunnett's table ($\alpha = .05$, two-tailed test). Therefore, the mean number of targets killed by the platoon in Condition C is not significantly different from the mean number in Condition D.

b. Dependent Variable V143 = Average Range at Intercept for Targets Killed by Platoon (in kilometers)

ANOVA Results:

Experimental Condition	Mean	Std.Dev	F	p	Order of Closeness to D
A	3.032	.345	4.26	.0056	BAC
B	3.136	.419			
C	2.947	.491			
Control Condition					
D	3.115	.402			

Dunnett's t Results:

(1) Condition A vs. Condition D

t = -1.4053291

This t statistic is less than the critical value (i.e., t = 2.37) found in Dunnett's table (α = .05, two-tailed test). Therefore, the mean "average range at intercept for targets killed by platoon" in Condition A is not significantly different from the mean "average range" in Condition D.

(2) Condition B vs. Condition D

t = .3555652

This t statistic is less than the critical value (i.e., t = 2.37) found in Dunnett's table (α = .05, two-tailed test). Therefore, the mean "average range at intercept for targets killed by platoon" in Condition B is not significantly different from the mean "average range" in Condition D.

(3) Condition C vs. Condition D

t = -2.8445215

This t statistic is greater than the critical value (i.e., t = 2.37) found in Dunnett's table (α = .05, two-tailed test). Therefore, the mean "average range at intercept for targets killed by platoon" in Condition C is significantly different from the mean "average range" in Condition D.

c. Dependent Variable V94 = Average Number of Targets Known to C2I System

ANOVA Results:

Experimental Condition	Mean	Std.Dev	F	p	Order of Closeness to D
A	8.18	.96	2.13	.095	BCA
B	7.99	.87			
C	8.17	1.00			
Control Condition					
D	7.90	.93			

Dunnett's t Results:

(1) Condition A vs. Condition D

$t = 2.1067886$

This t statistic is less than the critical value (i.e., $t = 2.37$) found in Dunnett's table ($\alpha = .05$, two-tailed test). Therefore, the mean number of targets known to the C2I system in Condition A is not significantly different from the mean number in Condition D.

(2) Condition B vs. Condition D

$t = .6771821$

The t statistic is less than the critical value (i.e., $t = 2.37$) found in Dunnett's table ($\alpha = .05$, two-tailed test). Therefore, the mean number of targets known to the C2I system in Condition B is not significantly different from the mean number in Condition D.

(3) Condition C vs. Condition D

$t = 2.0315461$

This t statistic is less than the critical value (i.e., $t = 2.37$) found in Dunnett's table ($\alpha = .05$, two-tailed test). Therefore, the mean number of targets known to the C2I system in Condition C is not significantly different from the mean number in Condition D.

d. The follow-on results for dependent variables associated with individual fire units are presented in Table 1.

Table 1

Ranking of Means: For Selected Dependent Variables Associated With Three Experimental Conditions

Dependent Variable No.	Means A	Means B	Means C	Means D	Ranks* A	Ranks* B	Ranks* C	Total
2	1.77	2.10	2.04	2.14	3	1	2	6
4	2.58	2.81	2.37	2.78	2	1	3	6
6	1.45	1.80	1.84	1.88	3	2	1	6
8	2.73	2.82	2.88	2.60	1	2	3	6
10	3.93	4.24	4.07	4.37	3	1	2	6
12	.91	1.04	1.03	1.25	3	1	2	6
24	3.02	3.19	3.16	3.21	3	1	2	6
39	3.93	3.87	3.97	3.83	2	1	3	6
52	.85	1.00	.99	1.16	3	1	2	6
54	3.01	3.25	3.13	3.08	2	3	1	6
55	6.37	5.81	6.05	5.77	3	1	2	6
56	4.01	3.60	3.50	3.47	3	2	1	6
60	1.08	1.23	1.14	1.39	3	1	2	6
66	10.55	11.18	11.40	9.88	1	2	3	6
67	11.28	11.48	9.51	8.74	2	3	1	6
69	13.87	12.37	12.20	12.50	3	1	2	6
75	14.72	13.23	13.58	13.78	3	2	1	6
90	2.52	2.52	2.52	2.60	2	2	2	6
104	4.73	4.66	4.73	4.59	2	1	3	6
106	3.62	3.57	3.62	3.51	3	1	2	6
114	.45	.37	.41	.38	3	1	2	6
116	.01	.01	.01	.01	2	2	2	6
118	.01	.01	.01	.01	2	2	2	6
119	.01	.01	.01	.01	2	2	2	6
124	22.84	23.43	21.43	21.02	2	3	1	6
n = 25				Total	61	40	49	150

* Ranked according to closeness to the mean for Control Condition D, with "1" representing the closest and "3" representing the farthest.

For the data in Table 1,

$$(1)\ \frac{G^2}{kn} = \frac{150^2}{(3)(25)} = 300 \qquad (2)\ \Sigma\Sigma X^2 = 342 \qquad (3)\ \frac{\Sigma T^2_j}{n} = \frac{61^2 + 40^2 + 49^2}{25} = 308.84$$

$$(4)\ \frac{\Sigma P^2_i}{k} = \frac{6^2(25)}{3} = 300$$

$SS_{conditions} = (3) - (1) = 262.57 - 252 = 10.57$
$SS_{residual} = (2) - (3) - (4) + (1) = 294 - 262.57 - 252 + 252 = 31.43$
$SS_{within\ variables} = (2) - (4) = 294 - 252 = 42$

Therefore, $$\chi^2_{ranks} = \frac{n(k-1)SS_{conditions}}{SS_{within\ variables}} = 10.52 \quad .$$

The critical value of this statistic for an $\alpha = .01$ test is:

$$\chi^2_{.99}(k-1) = \chi^2_{.99}(2) = 9.2 \quad .$$

Since the observed χ^2 exceeds the critical value, the data contradict the hypothesis of no difference between the mean ranks for the three experimental conditions. Thus, the ANOVA for ranked data revealed that there is a trend for Experimental Condition B (rather than Experimental Condition A or C) to yield results that are more similar to the results yielded by Control Condition D.

Conclusion

This experiment yielded a modicum of support for using a computer-aided threat evaluation algorithm similar to the one currently being used on the ADATS. This algorithm is associated with Experimental Condition B which assumes that all target engagement times (T_E) are equal to 10 seconds. The authors believe that additional research is needed to support the appropriateness of this algorithm for use under battlefield conditions different from those simulated in this model, i.e., under:

(1) different aerial scenarios -- i.e., different numbers and types of aircraft (fixed wing, rotary wing (running), and rotary wing (hovering)), different flight profiles, and different temporal sequencing of attack profiles,

(2) different digitized terrains used in the simulations of air defense engagements -- i.e., the terrains for flat, hilly, and mountainous regions, and

(3) different placements of the four fire units on the same digitized terrain.

REFERENCES

Dayton, C. M. (1970). The Design of Educational Experiments. New York: McGraw-Hill Book Company.

Moulton, S. W. (1988). Improved Performance of LOS-F-H Radar -- Draft 1 (Martin-Marietta Report). Orlando, FL: Martin-Marietta.

Pritsker, A. A. B. (1986). Introduction to Simulation and SLAM II (3rd ed.). New York: John Wiley & Sons.

Winer, B. J. (1971). Statistical Principles in Experimental Design. New York: McGraw-Hill Book Company.

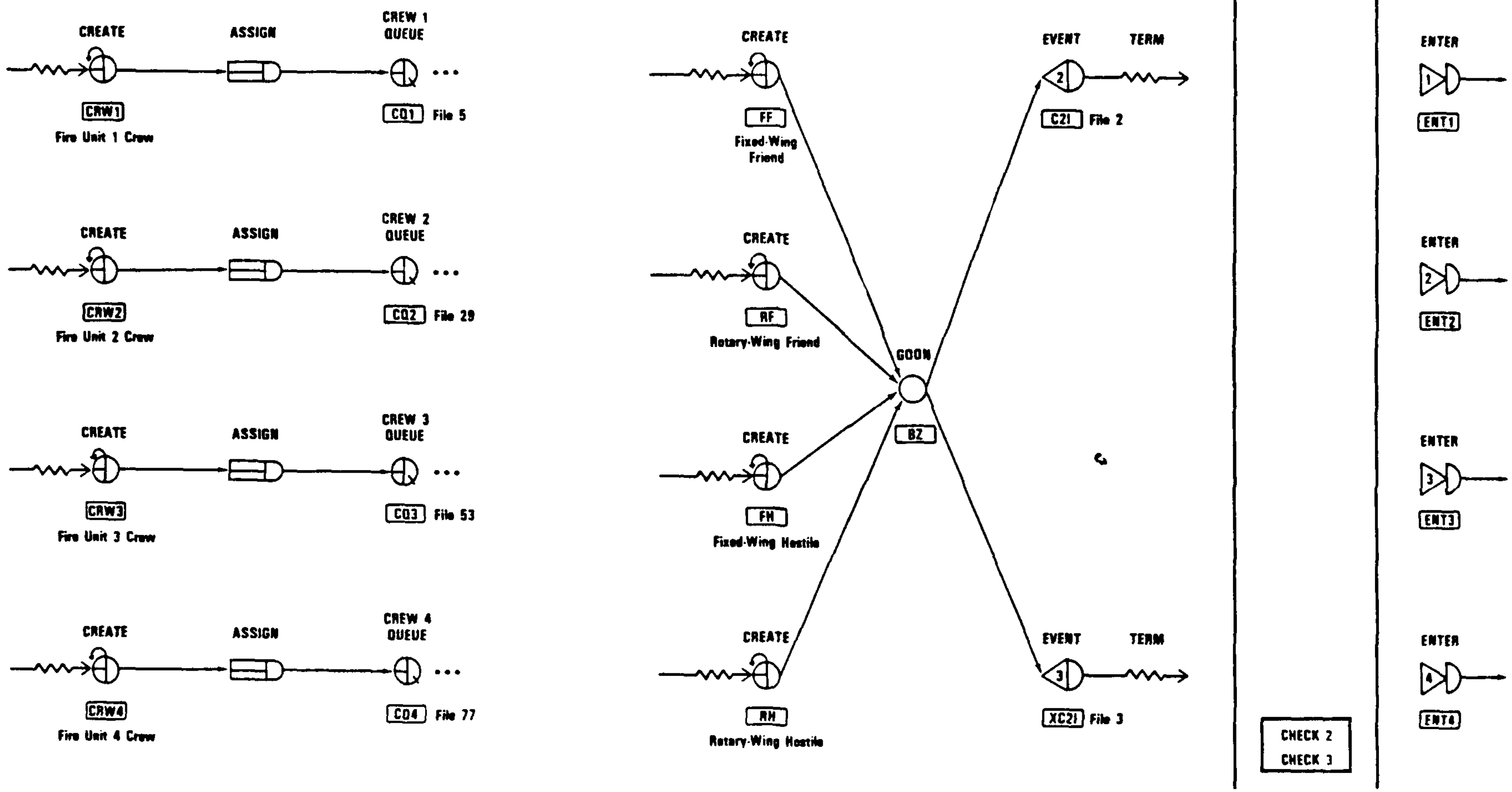
APPENDIX A

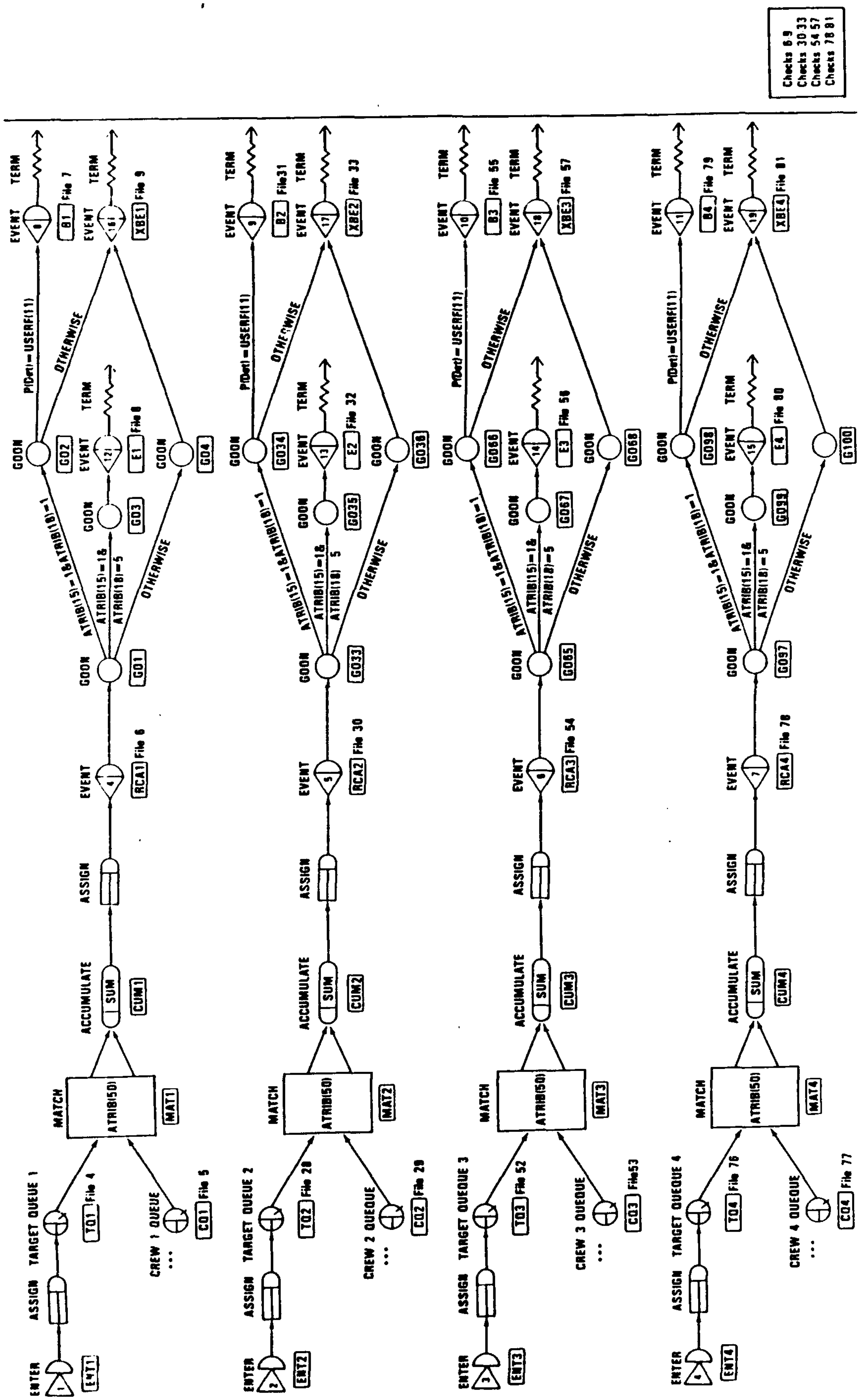
FLOW CHART: SLAM II MODEL OF AN ADA ENGAGEMENT SEQUENCE FOR AN ADATS LOS-F(H) PLATOON

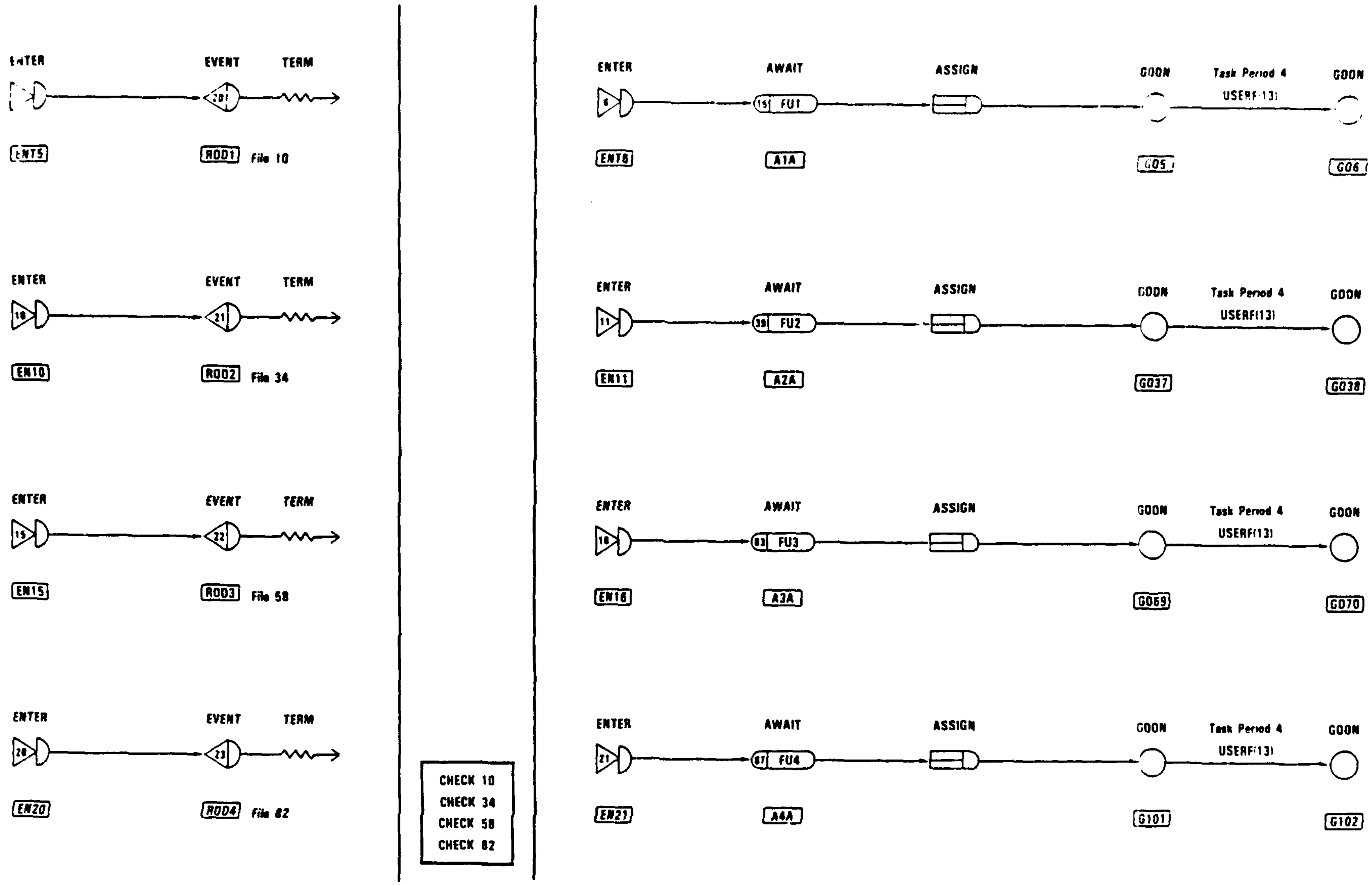
SLAM II MODEL OF AN ADA ENGAGEMENT SEQUENCE FOR AN ADATS LOS-F(H) PLATOON

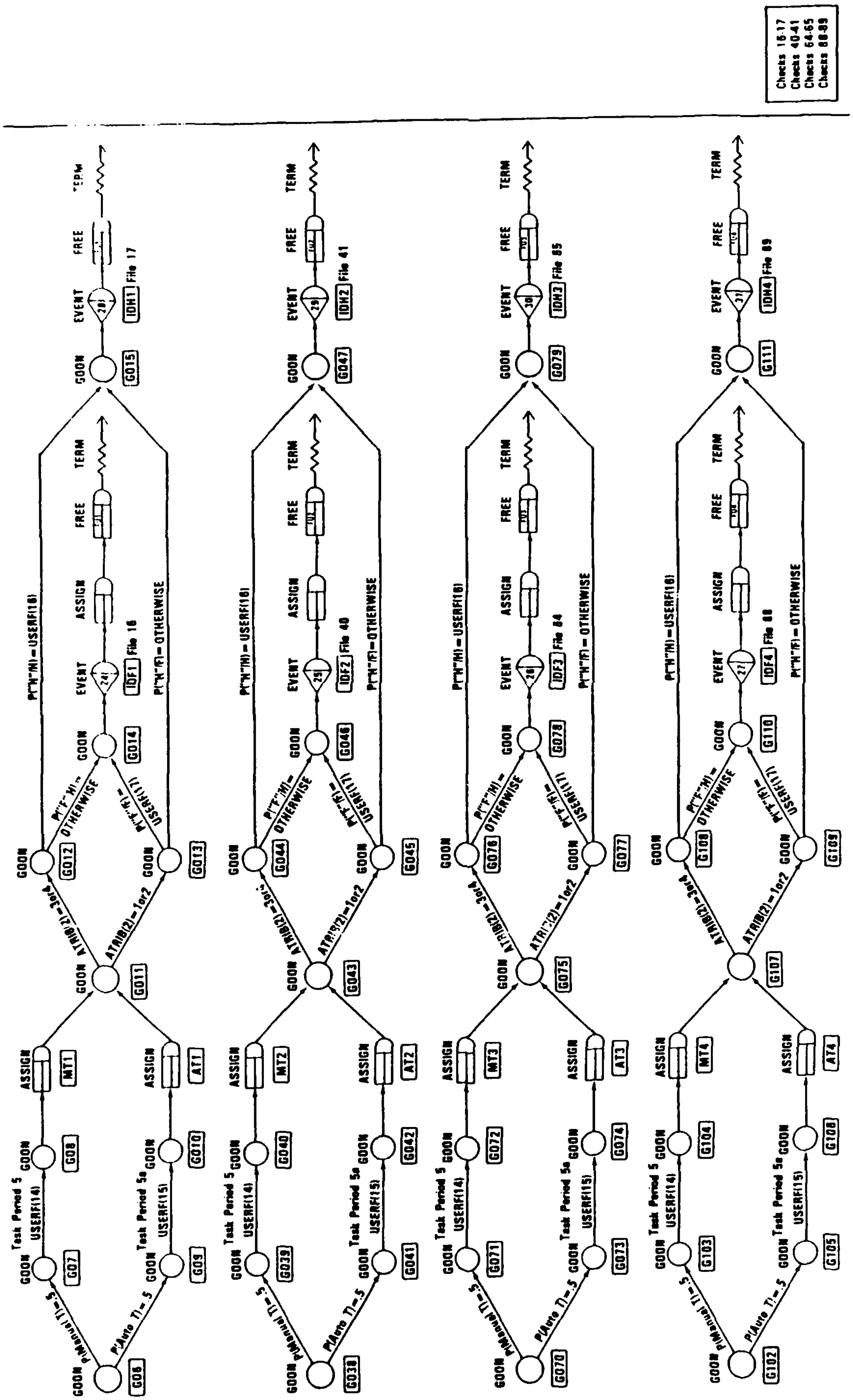
RESOURCE BLOCK

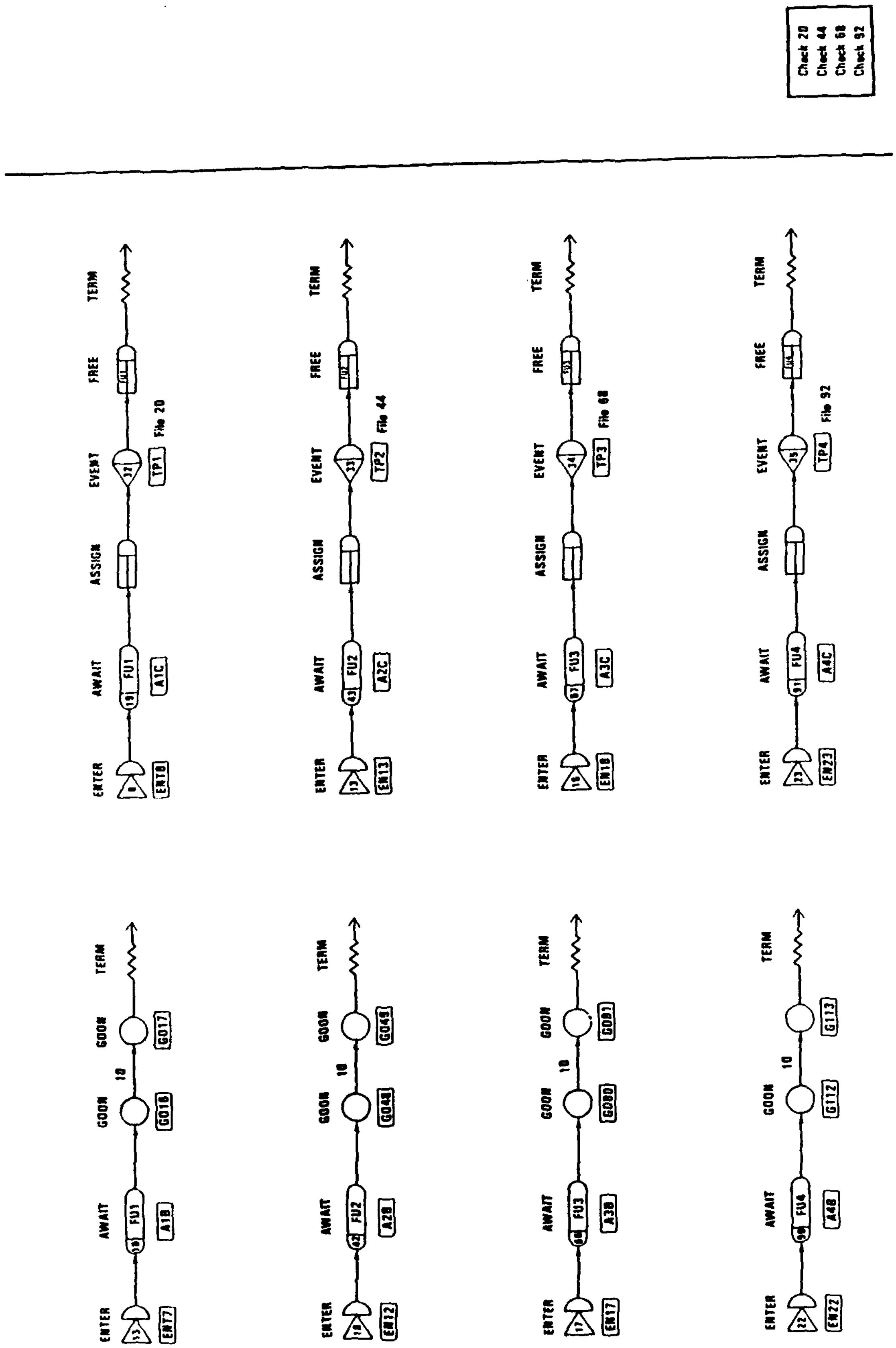
FU1(1)	15	18	19	21	22	23	24	25	26	27
FU2(1)	39	42	43	45	46	47	48	49	50	51
FU3(1)	63	66	67	69	70	71	72	73	74	75
FU4(1)	87	90	91	93	94	95	96	97	98	99

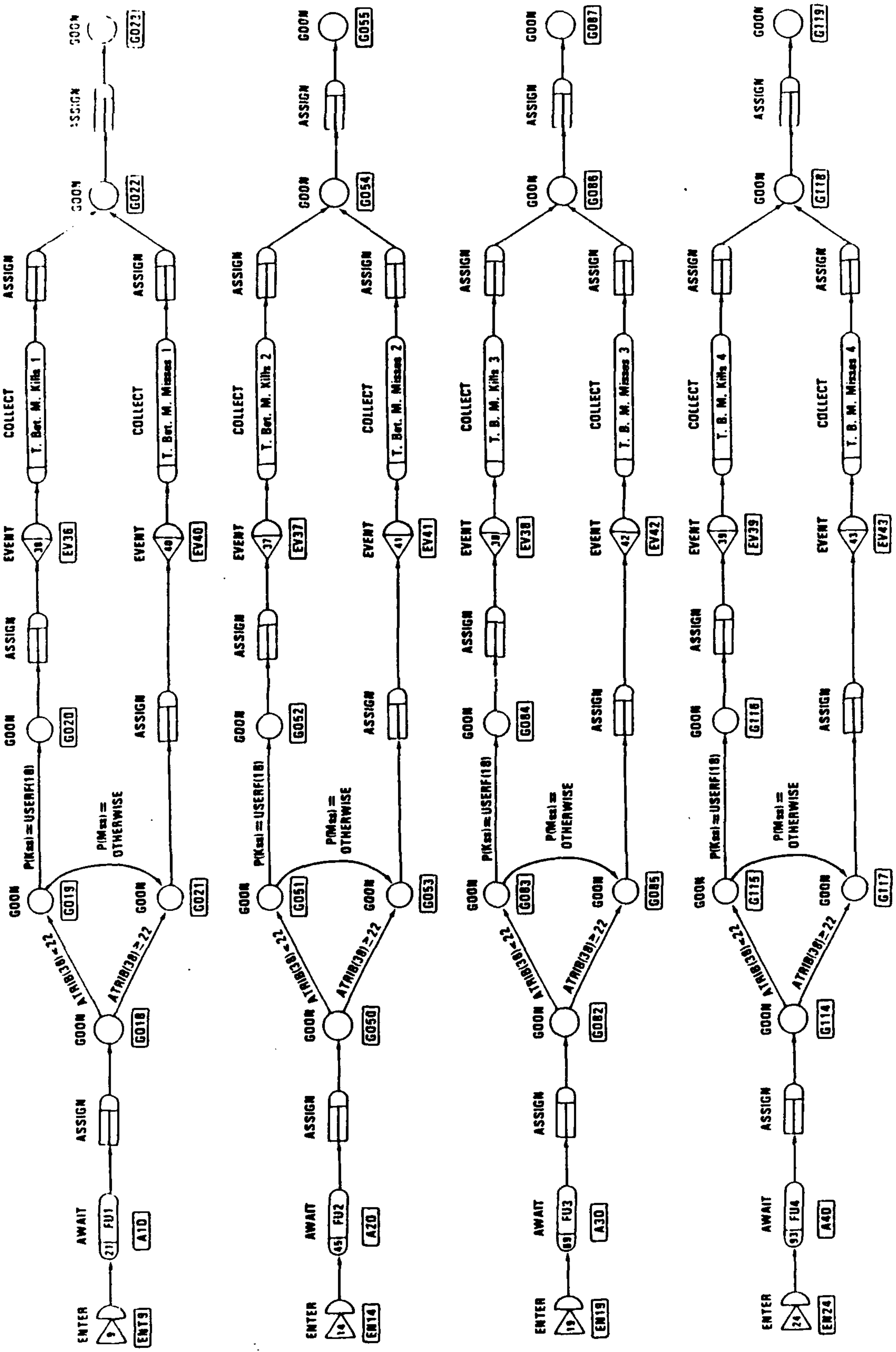



Checks 6-9
Checks 30-33
Checks 54-57
Checks 78-81
ENTER
ASSIGN
TARGET QUEUE 1
CREW 1 QUEUE
MATCH
ATRIB(50)
ACCUMULATE
SUM
EVENT
GOON
TERM
OTHERWISE
P(Detl)=USERF(11)
ATRIB(15)=1&ATRIB(18)=1
ATRIB(15)=1&
ATRIB(18)=5
ENT1
TQ1
CQ1
MAT1
CUM1
RCA1
G01
G02
G03
G04
E1
B1
XBE1
File 4
File 5
File 6
File 7
File 8
File 9
TARGET QUEUE 2
CREW 2 QUEUE
TARGET QUEUE 3
CREW 3 QUEUE
TARGET QUEUE 4
CREW 4 QUEUE


ENTER
EVENT
TERM
ENT5
ROD1
File 10
ENTER
EVENT
TERM
EN10
ROD2
File 34
ENTER
EVENT
TERM
EN15
ROD3
File 58
ENTER
EVENT
TERM
EN20
ROD4
File 82
CHECK 10
CHECK 34
CHECK 58
CHECK 82
ENTER
AWAIT
ASSIGN
GOON
Task Period 4
USERF(13)
GOON
ENT8
FU1
A1A
G05
G06
ENTER
AWAIT
ASSIGN
GOON
Task Period 4
USERF(13)
GOON
EN11
FU2
A2A
GO37
GO38
ENTER
AWAIT
ASSIGN
GOON
Task Period 4
USERF(13)
GOON
EN16
FU3
A3A
GO69
GO70
ENTER
AWAIT
ASSIGN
GOON
Task Period 4
USERF(13)
GOON
EN21
FU4
A4A
G101
G102


Checks 16-17
Checks 40-41
Checks 64-65
Checks 88-89


Check 20
Check 44
Check 68
Check 92
ENTER
AWAIT
ASSIGN
EVENT
FREE
TERM
GOON
FU1
FU2
FU3
FU4
A1C
A2C
A3C
A4C
A1B
A2B
A3B
A4B
TP1
TP2
TP3
TP4
File 20
File 44
File 68
File 92
EN13
EN18
EN23
EN12
EN17
EN22
G016
G017
G048
G049
G080
G081
G112
G113
10



ENTER
AWAIT
ASSIGN
GOON
EVENT
COLLECT
ATRIB(38)<22
ATRIB(38)≥22
P(Kss) = USERF(18)
P(Mss) = OTHERWISE
T. Bat. M. Kills 1
T. Bat. M. Misses 1
T. Bat. M. Kills 2
T. Bat. M. Misses 2
T. B. M. Kills 3
T. B. M. Misses 3
T. B. M. Kills 4
T. B. M. Misses 4
EN9
A10
FU1
G018
G019
G020
G021
EV36
EV40
G022
G023
EN14
A20
FU2
G050
G051
G052
G053
EV37
EV41
G054
G055
EN19
A30
FU3
G082
G083
G084
G085
EV38
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G114
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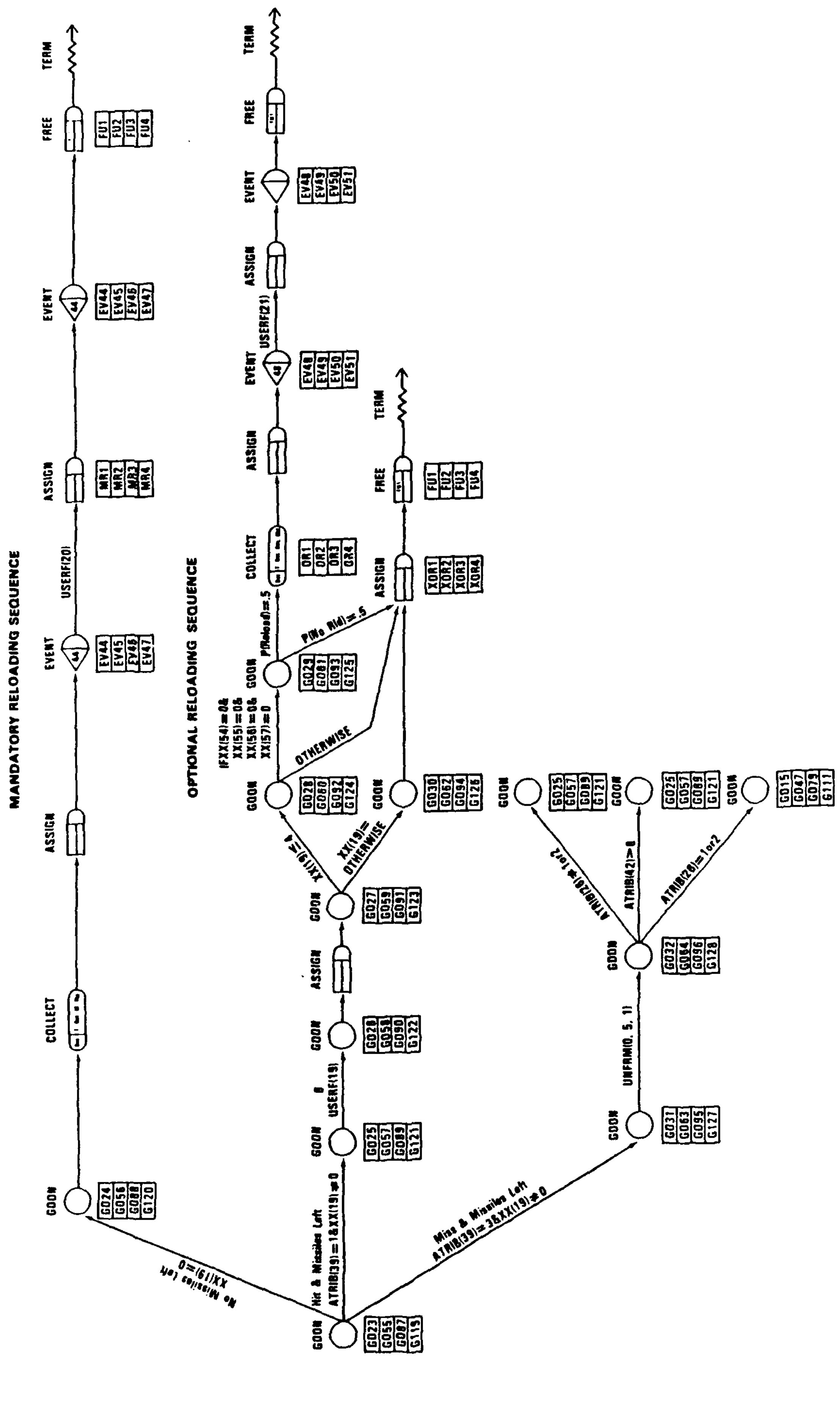
EV39
EV43
G118
G119



MANDATORY RELOADING SEQUENCE
GOON
COLLECT
ASSIGN
EVENT
USERF(20)
ASSIGN
EVENT
FREE
TERM
G024 G056 G088 G120
EV44 EV45 EV46 EV47
MR1 MR2 MR3 MR4
FU1 FU2 FU3 FU4
OPTIONAL RELOADING SEQUENCE
No Missiles Left XX(19)=0
Hit & Missiles Left ATRIB(39)=1&XX(19)≠0
Miss & Missiles Left ATRIB(39)=3&XX(19)≠0
G023 G055 G087 G119
USERF(19)
G025 G057 G089 G121
G026 G058 G090 G122
G027 G059 G091 G123
XX(19)=4
XX(19)= OTHERWISE
IF XX(54)=0& XX(55)=0& XX(56)=0& XX(57)=0
OTHERWISE
G028 G060 G092 G124
P(Reload)=.5
P(No Rld)=.5
G029 G061 G093 G125
OR1 OR2 OR3 OR4
USERF(21)
EV48 EV49 EV50 EV51
G030 G062 G094 G126
XOR1 XOR2 XOR3 XOR4
UNFRM(0, 5, 1)
G031 G063 G095 G127
G032 G064 G096 G128
ATRIB(26)≠1or2
ATRIB(42)>8
ATRIB(26)=1or2
G015 G047 G079 G111

Appendix B

EXAMPLE AND DESCRIPTION OF SCENARIO INPUT FILE

The first line in this data file gives the number of aircraft in the simulation (e.g., 020), the number of fire units (e.g., 004), and the number of vertical rectangular blinds (e.g., 005) which represent fog, smoke, or other battlefield obscurants blocking certain Lines-of-Sight for the fire units.

The flight profiles of the simulated aircraft are presented next. A flight profile for an aircraft consists of rows of eight-columned data that represent:

1) the initial X-Y-Z location of the aircraft, measured in kilometers from an arbitrary, sea-level origin -- i.e., data in columns 1-3 of row 1 in each profile;

2) the creation time of the aircraft entity -- i.e., data in column 4 of row 1 in each profile;

3) the X-Y-Z location of the first waypoint that the aircraft flies to -- i.e., data in columns 1-3 of row 2. If the aircraft is a pop-up helicopter, the X and Y coordinates of the initial position are identical to the X and Y coordinates of the first waypoint;

4) the aircraft velocity in km/sec from the initial position to the first waypoint -- i.e., the data in column 4 of row 2 in each profile. [This column contains data if the velocity is constant and is left blank if accelerated or decelerated flight is involved between the initial position and the first waypoint for each profile.];

5) the beginning velocity in km/sec at the initial position -- i.e., data in column 5 of row 2, and the ending velocity in km/sec at the first waypoint - i.e., data in column 6 of row 2. [These two columns contain data if accelerated or decelerated flight is involved, but are left blank if constant-velocity flight is involved.];

6) the height in feet above the terrain for nap-of-earth (NOE) flight -- i.e., the data in column 7 of row 2. [This column contains data if NOE flight is planned. In these cases, the Z coordinate data in column 3 for rows 1-2 are ignored. The column is left blank if NOE flight is not planned for the initial leg.].

The waypoint-to-waypoint flight profile for each aircraft is terminated by leaving blanks in columns 1-7 and entering "99." in column 8.

The movement profiles for the simulated fire units are presented next. During any simulation, a fire unit may be stationary or it may move from one ground-level waypoint to another ground-level waypoint at a constant velocity. Columns 1-2 of row 1 in a fire unit profile contain the X and Y coordinates of the fire unit. Column 3 contains a 0, but the actual Z coordinate is the Z coordinate associated with the X and Y coordinates on the digitized terrain.

Column 4 contains a 0 if the fire unit is at that location at the beginning of the simulation. For a stationary fire unit, the data in columns 1-3 of row 2 are identical to the data in columns 1-3 of row 1. The data in column 4 of row 2 represent the number of seconds that the fire unit is stationary at a particular location. For a fire unit that moves from its initial position to a new waypoint, the data in columns 1-2 of row 1 are different from the data in columns 1-2 of row 2 and the numerical value in column 4 of row 2 represents the constant velocity in km/sec that the fire unit travels between the two points. The input format allows the scenario developer to move a fire unit for a while, stop it to fight, move it to another fighting position, stop it there, etc. Several rows of data would be input for a fire unit that moves in this manner. All fire unit profiles are concluded by placing a "99." in column 5.

Vertical blind data are presented next. One row of data pertains to each blind. Columns 1-2 contain the X and Y coordinates of a point at one corner of the blind. Columns 3-4 contain the X and Y coordinates of a point at another corner of the blind. The Z coordinates of both points are 0. Column 5 represents the height of the Z coordinate for the other two corners of the blind. Thus, a blind is a vertical rectangle that can be placed around the battlefield to represent fog, smoke, or other obscurants which block certain lines of sight of the electro-optic equipment.

Zone of interest data are presented next. Included are the azimuths, elevations, and ranges associated with the assigned zones of interest for the fire units, one row of data per fire unit. Column 1 contains one of the azimuths associated with the zone of interest for a particular fire unit. Azimuths are measured in degrees counterclockwise from the "East = 0°" direction. Column 2 contains the other azimuth for that zone of interest. Column 3 contains the lower elevation and column 4 contains the upper elevation of that zone of interest, both elevations measured in degrees from the 0° horizontal plane. Column 5 contains the range in kilometers of that zone of interest.

Fire zone data are presented next. Included are the elevation and range data for establishing fire zones for a hybrid LOS-F(H) system, i.e., a system that can fire guns, as well as missiles, at aerial targets. Rows 1-3 contain data for two fire zones which permit missile fire and one fire zone which does not. Row 1 contains elevation and range data for establishing the outer limits of these 3 fire zones. Column 1 of row 1 contains the lower elevation angle (measured in degrees from the 0° horizontal plane). Column 2 of row 1 contains the upper elevation angle (measured in degrees from the 0° horizontal plane). Column 3 of row 3 contains the range of the radar (measured in kilometers from the fire unit). The larger "pie" outlined via row 1 data is divided into three segments by using row 2 and row 3 data - i.e., these two rows have elevation data identical to elevation data in row 1, but with different range data.

In a 0° to 65° pie, Fire Zone 1 goes from Range = 8 km to Range = 20 km. Neither guns nor missiles should be fired at targets in this zone. Fire Zone 2 goes from Range = 4 km to Range = 8 km. Only missiles should be fired at targets in this zone. Fire Zone 3 goes from Range = 0 to Range = 4 km. Both guns and missiles may be fired at targets in this zone.

Row 4 contains elevation and range data for establishing the outer limits of 2 more fire zones. Column 1 of row 4 contains the lower elevation angle and column 2 of row 4 contains the upper elevation angle. Column 3 of row 4 contains the range of the radar. The larger "pie" outlined via row 4 data is divided into two segments by using row 5 data.

In a 65° to 75° pie, Fire Zone 4 goes from Range = 4 km to Range = 20 km. Neither guns nor missiles should be fired at a target in this zone. Fire Zone 5 goes from Range = 0 to Range = 4 km. Only guns should be fired at targets in this zone.

Row 6 contains elevation and range data for establishing the outer limits of the last fire zone -- Fire Zone 6. In the 75° to 90° pie, Fire Zone 6 goes from Range = 0 to Range = 20 km. Neither guns nor missiles should be fired at targets in Fire Zone 6.

```
020004005
 5.0   * 16.6  *  8.6  *  .99  *       *       *       *        *
 8.4   * 15.6  *  8.4  *  .08  *       *       *  10.  *        *
 8.6   * 15.4  *  2.6  *       * .049  *  .045 * 400.  *        *
 9.0   * 15.2  *  2.6  *       * .045  *  .049 * 200.  *        *
 8.7   * 14.5  *  2.6  *       * .049  *  .045 *  10.  *        *
 8.0   * 14.2  *  2.6  *  .045 *       *       *  10.  *        *
 7.0   * 14.2  *  8.4  *  .045 *       *       *  10.  *        *
 6.0   * 15.2  *  2.6  *  .045 *       *       *  10.  *        *
 5.0   * 16.6  *  2.6  *       * .045  *  .049 *  10.  *        *
 8.4   * 15.6  *  8.4  *  .049 *       *       *  10.  *        *
 8.6   * 15.4  *  2.6  *       * .049  *  .045 * 400.  *        *
 9.0   * 15.2  *  2.6  *       * .045  *  .049 * 200.  *        *
 8.7   * 14.5  *  2.6  *       * .045  *  .049 *  10.  *        *
 8.0   * 14.2  *  2.6  *  .049 *       *       *  10.  *        *
 7.0   * 14.2  *  8.4  *  .049 *       *       *  10.  *        *
 6.0   * 15.2  *  2.6  *  .049 *       *       *  10.  *        *
 5.0   * 16.6  *  8.6  *  .049 *       *       *  10.  *        *
 8.4   * 15.6  *  8.4  *  .08  *       *       *  10.  *        *
 8.6   * 15.4  *  2.6  *       * .049  *  .045 * 400.  *        *
 9.0   * 15.2  *  2.6  *       * .045  *  .049 * 200.  *        *
 8.7   * 14.5  *  2.6  *       * .049  *  .045 *  10.  *        *
 8.0   * 14.2  *  2.6  *  .045 *       *       *  10.  *        *
 7.0   * 14.2  *  8.4  *  .045 *       *       *  10.  *        *
 6.0   * 15.2  *  2.6  *  .045 *       *       *  10.  *        *
 5.0   * 16.6  *  2.6  *       * .045  *  .049 *  10.  *        *
 8.4   * 15.6  *  8.4  *  .049 *       *       *  10.  *        *
 8.6   * 15.4  *  2.6  *       * .049  *  .045 * 400.  *        *
 9.0   * 15.2  *  2.6  *       * .045  *  .049 * 200.  *        *
 8.7   * 14.5  *  2.6  *       * .045  *  .049 *  10.  *        *
 8.0   * 14.2  *  2.6  *  .049 *       *       *  10.  *        *
       *       *       *       *       *       *       *99.     *
 5.0   * 16.8  *  8.6  * 1.99  *       *       *       *        *
 8.4   * 15.8  *  8.4  *  .08  *       *       *  10.  *        *
 8.6   * 15.6  *  2.6  *       * .049  *  .045 * 400.  *        *
 9.2   * 15.3  *  2.6  *       * .045  *  .049 * 200.  *        *
 8.7   * 14.3  *  2.6  *       * .049  *  .045 *  10.  *        *
 8.0   * 14.0  *  2.6  *  .045 *       *       *  10.  *        *
 7.0   * 14.0  *  8.4  *  .045 *       *       *  10.  *        *
 6.0   * 15.0  *  2.6  *  .045 *       *       *  10.  *        *
 5.0   * 16.8  *  8.6  *  .045 *       *       *  10.  *        *
 8.4   * 15.8  *  8.4  *  .045 *       *       *  10.  *        *
 8.6   * 15.6  *  2.6  *       * .045  *  .049 * 400.  *        *
 9.2   * 15.3  *  2.6  *       * .045  *  .049 * 200.  *        *
 8.7   * 14.3  *  2.6  *       * .049  *  .045 *  10.  *        *
 8.0   * 14.0  *  2.6  *  .045 *       *       *  10.  *        *
 7.0   * 14.0  *  8.4  *  .045 *       *       *  10.  *        *
 6.0   * 15.0  *  2.6  *  .045 *       *       *  10.  *        *
 5.0   * 16.8  *  8.6  *  .045 *       *       *  10.  *        *
 8.4   * 15.8  *  8.4  *  .08  *       *       *  10.  *        *
 8.6   * 15.6  *  2.6  *       * .049  *  .045 * 400.  *        *
 9.2   * 15.3  *  2.6  *       * .045  *  .049 * 200.  *        *
 8.7   * 14.3  *  2.6  *       * .049  *  .045 *  10.  *        *
 8.0   * 14.0  *  2.6  *  .045 *       *       *  10.  *        *
 7.0   * 14.0  *  8.4  *  .045 *       *       *  10.  *        *
```

020004005

5.0	16.6	8.6	.99				
8.4	15.6	8.4	.08			10.	
8.6	15.4	2.6		.049	.045	400.	
9.0	15.2	2.6		.045	.049	200.	
8.7	14.5	2.6		.049	.045	10.	
8.0	14.2	2.6	.045			10.	
7.0	14.2	8.4	.045			10.	
6.0	15.2	2.6	.045			10.	
5.0	16.6	2.6		.045	.049	10.	
8.4	15.6	8.4	.049			10.	
8.6	15.4	2.6		.049	.045	400.	
9.0	15.2	2.6		.045	.049	200.	
8.7	14.5	2.6		.045	.049	10.	
8.0	14.2	2.6	.049			10.	
7.0	14.2	8.4	.049			10.	
6.0	15.2	2.6	.049			10.	
5.0	16.6	8.6	.049			10.	
8.4	15.6	8.4	.08			10.	
8.6	15.4	2.6		.049	.045	400.	
9.0	15.2	2.6		.045	.049	200.	
8.7	14.5	2.6		.049	.045	10.	
8.0	14.2	2.6	.045			10.	
7.0	14.2	8.4	.045			10.	
6.0	15.2	2.6	.045			10.	
5.0	16.6	2.6		.045	.049	10.	
8.4	15.6	8.4	.049			10.	
8.6	15.4	2.6		.049	.045	400.	
9.0	15.2	2.6		.045	.049	200.	
8.7	14.5	2.6		.045	.049	10.	
8.0	14.2	2.6	.049			10.	
							99.
5.0	16.8	8.6	1.99				
8.4	15.8	8.4	.08			10.	
8.6	15.6	2.6		.049	.045	400.	
9.2	15.3	2.6		.045	.049	200.	
8.7	14.3	2.6		.049	.045	10.	
8.0	14.0	2.6	.045			10.	
7.0	14.0	8.4	.045			10.	
6.0	15.0	2.6	.045			10.	
5.0	16.8	8.6	.045			10.	
8.4	15.8	8.4	.045			10.	
8.6	15.6	2.6		.045	.049	400.	
9.2	15.3	2.6		.045	.049	200.	
8.7	14.3	2.6		.049	.045	10.	
8.0	14.0	2.6	.045			10.	
7.0	14.0	8.4	.045			10.	
6.0	15.0	2.6	.045			10.	
5.0	16.8	8.6	.045			10.	
8.4	15.8	8.4	.08			10.	
8.6	15.6	2.6		.049	.045	400.	
9.2	15.3	2.6		.045	.049	200.	
8.7	14.3	2.6		.049	.045	10.	
8.0	14.0	2.6	.045			10.	
7.0	14.0	8.4	.045			10.	

```
 30.    *180.    * -5.0   *90.0    *  20.0  *        *        *        *
0.00    *65.0    *20.0    *        *        *        *        *        *
0.00    *65.0    *8.0     *        *        *        *        *        *
0.00    *65.0    *4.0     *        *        *        *        *        *
65.0    *65.0    *20.0    *        *        *        *        *        *
65.0    *65.0    * 4.0    *        *        *        *        *        *
65.0    *90.0    *20.0    *        *        *        *        *        *
```

Appendix C

CONTENTS OF THREE STATUS ARRAYS

FORTRAN subroutines are called every second during a simulation run to update the data in three status arrays: ARRAY 1 (100, 24, 4), ARRAY 2 (6, 4), and ARRAY 3 (100, 4, 4). Numerous mathematical formulas are coded in the subroutines. These formulas use scenario-type information contained in the YTRACK DATA file (e.g., flight profiles of aircraft, velocity of aircraft, fire unit locations, dimensions of zones of interest, and dimensions of fire zone envelopes) and digitized terrain data to determine the second-by-second status of each target-fire unit combination.

ARRAY 1 (100, 24, 4) contains 24 items of information on every target-fire unit combination in the model, i.e., 24 items of information on a maximum of 400 target-fire unit combinations. In the current LOS-F(H) model, 20 targets (instead of 100) are combined with 4 fire units -- thus, ARRAY 1 is updated each second for Target 1-Fire Unit 1, Target 1-Fire Unit 2, Target 1-Fire Unit 3, Target 1-Fire Unit 4, etc. The 24 items of information updated each second for each target-fire unit combination are:

Variable Number	Type of Information
1	Azimuth at TNOW-1
2	Elevation at TNOW-1
3	Range at TNOW-1
4	X coordinate at TNOW-1
5	Y coordinate at TNOW-1
6	Z coordinate at TNOW-1
7	Masking Status at TNOW-1 1 - Not Masked 0 - Masked
8	Zone of Interest Status at TNOW-1 1 - In Zone of Interest for fire unit 0 - Not in Zone of Interest for fire unit
9	Fire Zone Status at TNOW-1 1 - In Fire Zone A where missiles, guns, or nothing may be fired -- depending on range of target 2 - In Fire Zone B where guns or nothing may be fired -- depending on range of target 3 - In Dead Zone where nothing may be fired

10	Velocity at TNOW-1
11	Distance to Primary Target Line at TNOW-1
12	Estimated Time of Arrival to fire unit at TNOW-1
13-24	Same as above except data is for TNOW

The TNOW and TNOW-1 data contained in ARRAY 1 allow the modeling of dynamic situations that occur during air defense engagements. For instance, a target may be unmasked to a particular fire unit at TNOW-1, but masked from that fire unit at TNOW. If the fire unit's crew has been proceeding through an engagement sequence for that target, the crew must react appropriately to the masking. In a real situation, the crew should wait 3 to 5 seconds for the target to unmask so that engagement procedures can continue. If the target does not unmask within that time period, the crew should commence engagement of another target -- if another one meets the engagement criteria. Dynamic situations like the one described above can be simulated by using the Preempt Node in the SLAM II simulation language.

ARRAY 2 (6, 4) contains 6 items of information on each of 4 fire units. The information is related to each fire unit's location at TNOW and its location at TNOW-1. The 6 items of information updated each second for each fire unit are:

Variable Number	Type of Information
1	X coordinate for fire unit at TNOW
2	Y coordinate for fire unit at TNOW
3	Z coordinate for fire unit at TNOW
4	X coordinate for fire unit at TNOW-1
5	Y coordinate for fire unit at TNOW-1
6	Z coordinate for fire unit at TNOW-1

If a fire unit does not move, the X, Y, and Z coordinates at TNOW are identical to the respective X, Y, and Z coordinates at TNOW-1. The exact location of each fire unit is used to calculate numerous values, such as the range from a fire unit to a target.

Appendix D

LIST OF DEPENDENT VARIABLES

User-Written Variables for Fire Unit 1:

Variable #	Variable Name
V1	No. of Trigger Pulls by Gunner 1
V2	No. of Targets Killed by Gunner 1
V3	No. of Targets Missed by Gunner 1
V4	Avg. Range at Impact for Targets Killed by Gunner 1
V5	Avg. Range at Miss for Targets Missed by Gunner 1
V6	No. of Hostile Targets Killed by Gunner 1
V7	No. of Friendly Targets Killed by Gunner 1
V8	No. of Ordnance Releases by Hostile Targets at Fire Unit 1
V9	Avg. Range to Fire Unit 1 at Ordnance Release
V10	No. of Hostile Targets Identified by Gunner 1
V11	No. of Hostile Targets Visually Identified as "Hostiles" by Gunner 1
V12	No. of Hostile Targets Visually Identified as "Friends" by Gunner 1
V13	No. of Friendly Targets Visually Identified by Gunner 1
V14	No. of Friendly Targets Visually Identified as "Friends" by Gunner 1
V15	No. of Friendly Targets Visually Identified as "Hostiles" by Gunner 1

User-Written Variables for Fire Unit 2:

Variable #	Variable Name
V16	No. of Trigger Pulls by Gunner 2
V17	No. of Targets Killed by Gunner 2
V18	No. of Targets Missed by Gunner 2
V19	Avg. Range at Impact for Targets Killed by Gunner 2
V20	Avg. Range at Miss for Targets Missed by Gunner 2
V21	No. of Hostile Targets Killed by Gunner 2
V22	No. of Friendly Targets Killed by Gunner 2
V23	No. of Ordnance Releases by Hostile Targets at Fire Unit 2
V24	Avg. Range to Fire Unit 2 at Ordnance Release
V25	No. of Hostile Targets Identified by Gunner 2
V26	No. of Hostile Targets Visually Identified as "Hostiles" by Gunner 2
V27	No. of Hostile Targets Visually Identified as "Friends" by Gunner 2
V28	No. of Friendly Targets Visually Identified by Gunner 2
V29	No. of Friendly Targets Visually Identified as "Friends" by Gunner 2
V30	No. of Friendly Targets Visually Identified as "Hostiles" by Gunner 2

User-Written Variables for Fire Unit 3:

Variable #	Variable Name
V31	No. of Trigger Pulls by Gunner 3
V32	No. of Targets Killed by Gunner 3
V33	No. of Targets Missed by Gunner 3
V34	Avg. Range at Impact for Targets Killed by Gunner 3
V35	Avg. Range at Miss for Targets Missed by Gunner 3
V36	No. of Hostile Targets Killed by Gunner 3
V37	No. of Friendly Targets Killed by Gunner 3
V38	No. of Ordnance Releases by Hostile Targets at Fire Unit 3
V39	Avg. Range to Fire Unit 3 at Ordnance Release
V40	No. of Hostile Targets Identified by Gunner 3
V41	No. of Hostile Targets Visually Identified as "Hostiles" by Gunner 3
V42	No. of Hostile Targets Visually Identified as "Friends" by Gunner 3
V43	No. of Friendly Targets Visually Identified by Gunner 3
V44	No. of Friendly Targets Visually Identified as "Friends" by Gunner 3
V45	No. of Friendly Targets Visually Identified as "Hostiles" by Gunner 3

User-Written Variables for Fire Unit 4:

Variable #	Variable Name
V46	No. of Trigger Pulls by Gunner 4
V47	No. of Targets Killed by Gunner 4
V48	No. of Targets Missed by Gunner 4
V49	Avg. Range at Impact for Targets Killed by Gunner 4
V50	Avg. Range at Miss for Targets Missed by Gunner 4
V51	No. of Hostile Targets Killed by Gunner 4
V52	No. of Friendly Targets Killed by Gunner 4
V53	No. of Ordnance Releases by Hostile Targets at Fire Unit 4
V54	Avg. Range to Fire Unit 4 at Ordnance Release
V55	No. of Hostile Targets Identified by Gunner 4
V56	No. of Hostile Targets Visually Identified as "Hostiles" by Gunner 4
V57	No. of Hostile Targets Visually Identified as "Friends" by Gunner 4
V58	No. of Friendly Targets Visually Identified by Gunner 4
V59	No. of Friendly Targets Visually Identified as "Friends" by Gunner 4
V60	No. of Friendly Targets Visually Identified as "Hostiles" by Gunner 4

User-Written Variables for Platoon:

Variable #	Variable Name
V61	No. of Trigger Pulls by Platoon
V62	No. of Targets Killed by Platoon
V63	No. of Hostile Targets Killed by Platoon
V64	No. of Friendly Targets Killed by Platoon
V65	No. of Targets Missed by Platoon

User-Written, Task Performance Variables for Fire Unit 1:

Variable #	Variable Name
V66	Avg. Time from Radar Detect to Radar Operator Detect for Fire Unit 1
V67	Avg. Time from Radar Operator Detect to Handoff for Fire Unit 1
V68	Avg. Time from Handoff to Gunner Trigger Pull for Fire Unit 1

User-Written, Task Performance Variables for Fire Unit 2:

Variable #	Variable Name
V69	Avg. Time from Radar Detect to Radar Operator Detect for Fire Unit 2
V70	Avg. Time from Radar Operator Detect to Handoff for Fire Unit 2
V71	Avg. Time from Handoff to Gunner Trigger Pull for Fire Unit 2

User-Written, Task Performance Variables for Fire Unit 3:

Variable #	Variable Name
V72	Avg. Time from Radar Detect to Radar Operator Detect for Fire Unit 3
V73	Avg. Time from Radar Operator Detect to Handoff for Fire Unit 3
V74	Avg. Time from Handoff to Gunner Trigger Pull for Fire Unit 3

User-Written, Task Performance Variables for Fire Unit 4:

Variable #	Variable Name
V75	Avg. Time from Radar Detect to Radar Operator Detect for Fire Unit 4
V76	Avg. Time from Radar Operator Detect to Handoff for Fire Unit 4
V77	Avg. Time from Handoff to Gunner Trigger Pull for Fire Unit 4

SLAM II Time-Persistent Variables:

Variable #	Variable Name
V78	Crew 1 Status
V79	Crew 2 Status
V80	Crew 3 Status
V81	Crew 4 Status
V82	Actual Threat to Radar Coverage Area 1 (RCA 1)
V83	Actual Threat to Radar Coverage Area 2 (RCA 2)
V84	Actual Threat to Radar Coverage Area 3 (RCA 3)
V85	Actual Threat to Radar Coverage Area 4 (RCA 4)
V86	Perceived Threat to RCA 1
V87	Perceived Threat to RCA 2
V88	Perceived Threat to RCA 3
V89	Perceived Threat to RCA 4

SLAM II Time-Persistent Variables: (cont)

Variable #	Variable Name
V90	Perceived Threat to Zone of Interest 1 (ZI 1)
V91	Perceived Threat to Zone of Interest 2 (ZI 2)
V92	Perceived Threat to Zone of Interest 3 (ZI 3)
V93	Perceived Threat to Zone of Interest 4 (ZI 4)
V94	No. of Targets Known to C2I System
V95	No. of Targets Not Known to C2I System
V96	No. of Targets in RCA 1
V97	No. of Targets in RCA 2
V98	No. of Targets in RCA 3
V99	No. of Targets in RCA 4
V100	No. of Targets Appearing on Radar Scope for Fire Unit 1
V101	No. of Targets Appearing on Radar Scope for Fire Unit 2
V102	No. of Targets Appearing on Radar Scope for Fire Unit 3
V103	No. of Targets Appearing on Radar Scope for Fire Unit 4
V104	No. of Targets Not Appearing on Radar Scope for Fire Unit 1
V105	No. of Targets Not Appearing on Radar Scope for Fire Unit 2
V106	No. of Targets Not Appearing on Radar Scope for Fire Unit 3
V107	No. of Targets Not Appearing on Radar Scope for Fire Unit 4
V108	No. of Targets Detected by Radar Operator of Fire Unit 1
V109	No. of Targets Detected by Radar Operator of Fire Unit 2
V110	No. of Targets Detected by Radar Operator of Fire Unit 3
V111	No. of Targets Detected by Radar Operator of Fire Unit 4
V112	No. of Targets Identified as Friendly by Fire Unit 1
V113	No. of Targets Identified as Friendly by Fire Unit 2
V114	No. of Targets Identified as Friendly by Fire Unit 3
V115	No. of Targets Identified as Friendly by Fire Unit 4
V116	No. of Targets Identified as Hostile by Fire Unit 1
V117	No. of Targets Identified as Hostile by Fire Unit 2
V118	No. of Targets Identified as Hostile by Fire Unit 3
V119	No. of Targets Identified as Hostile by Fire Unit 4
V120	No. of Targets Fired Upon by Gunner 1, but awaiting Hit/Miss Outcome
V121	No. of Targets Fired Upon by Gunner 2, but awaiting Hit/Miss Outcome
V122	No. of Targets Fired Upon by Gunner 3, but awaiting Hit/Miss Outcome
V123	No. of Targets Fired Upon by Gunner 4, but awaiting Hit/Miss Outcome

SLAM II Based-On-Observations Variables for Fire Unit 1:

Variable #	Variable Name
V124	Time From Radar Operator Detect to Trigger Pull for Fire Unit 1
V125	Time Between Trigger Pulls for Fire Unit 1
V126	Time Between Hits for Fire Unit 1
V127	Time Between Misses for Fire Unit 1

SLAM II Based-On-Observations Variables for Fire Unit 2:

Variable #	Variable Name
V128	Time From Radar Operator Detect to Trigger Pull for Fire Unit 2
V129	Time Between Trigger Pulls for Fire Unit 2
V130	Time Between Hits for Fire Unit 2
V131	Time Between Misses for Fire Unit 2

SLAM II Based-On-Observations Variables for Fire Unit 3:

Variable #	Variable Name
V132	Time From Radar Operator Detect to Trigger Pull for Fire Unit 3
V133	Time Between Trigger Pulls for Fire Unit 3
V134	Time Between Hits for Fire Unit 3
V135	Time Between Misses for Fire Unit 3

SLAM II Based-On-Observations Variables for Fire Unit 4:

Variable #	Variable Name
V136	Time From Radar Operator Detect to Trigger Pull for Fire Unit 4
V137	Time Between Trigger Pulls for Fire Unit 4
V138	Time Between Hits for Fire Unit 4
V139	Time Between Misses for Fire Unit 4

User-Written Variables Related to Hits:

Variable #	Variable Name
V140	Target Hit
V141	Fire Unit that Hit Target (1, 2, 3, or 4)
V142	Simulation Time (TNOW) when Target was Hit
V143	Avg. Range at Intercept for Targets Killed by Platoon

User-Written Variables Related to Misses:

Variable #	Variable Name
V144	Target Missed
V145	Fire Unit that Missed Target (1, 2, 3, or 4)
V146	TNOW when Target was Missed

User-Written Variables Related to Ordnance Releases:

V147	Target that Released Ordnance
V148	Fire Unit Fired Upon by Target (1, 2, 3, or 4)
V149	TNOW when Ordnance was Released
V150	Distance from Fire Unit when Ordnance was Released